

and includes seven chapters which present both the results of original field- and laboratory-based research and appropriate reviews of existing published literature. The section opens with a review of granite weathering by Gerrard, and is followed by a comparative study of deep weathering in Ireland, Corsica and Brazil by Power and Smith. Experimental investigations of the effects of fire on rock weathering and of weathering due to short-term rock temperature fluctuations are described by Allison and Goudie and by Warnke and Smith, respectively. The nature and importance of crack propagation is discussed by Douglas *et al.* in the context of basalt weathering in Northern Ireland, while the importance of volcanic gases in the development of weathering rinds on adesitic blocks in Japan is the focus of a paper by Matsukura *et al.* The section ends with a paper by Viles and Pentecost which discusses the problems involved in assessing the sometimes ambiguous evidence concerning weathering action of lichens on sandstone surfaces.

Section 2 contains five papers which examine weathering processes in the context of the weathering of building stones in urban areas and coastal environments. Weathering of limestones and sandstones due to airborne deposition from polluted urban atmospheres is discussed by Inkpen *et al.* and by Smith *et al.*, respectively. The importance of saline spray and wave splash in the deterioration of marine masonry is convincingly demonstrated in the two following papers by Mottershead and Takahashi *et al.*, while Cooke provides a clear illustration of the role of rising groundwater tables in contributing to enhanced damage to buildings caused by salt weathering in Central Asia.

Section 3 includes four papers which examine the implications of weathering for dating and the elucidation of landscape development. Contributions by Swanteson, Sjöberg and Woodward *et al.* demonstrate quite different techniques for the characterization of weathered surfaces and weathered materials which can be used to provide a means of relative age dating, while Parish discusses some of the difficulties which weathering of feldspars and other minerals may present in the application of absolute dating methods such as luminescence dating.

Section 4 contains five papers which consider the relationships between weathering and landform development in humid tropical and arid environments. The first three papers, by Thomas, Teeuw, and McFarlane *et al.*,

follow a fairly traditional approach in their consideration of the relationships between humid tropical weathering profiles, geomorphic surfaces, and long-term landscape evolution. The importance of tropical weathering processes and their influences on the engineering properties of materials is demonstrated by Fan *et al.*, while Schmidt demonstrates the links between lithology, structure, differential weathering and the development of the plan morphology of cuesta scarps under arid weathering conditions. Section 5 contains four contributions which explore similar themes in the context of temperate environments, including chapters on sandstone weathering processes and phenomena (Robinson and Williams), Dartmoor tors (Ehlen), the development of weathering flutes on siliceous rocks (Williams and Robinson), and limestone weathering in the intertidal zone of Mallorca (Moses and Smith). The final section focuses on weathering and landform development in high latitude and high altitude environments, with chapters dealing with lithological and structure controls on the development of cirques and lake basins (Evans), joint control in the formation of sub-glacial rock steps (Rea), and silt production during weathering of metamorphic rocks in the southern Himalayas (Gardner).

The majority of the contributions are very well written and contain significant new insights and/or original research results. The editors have performed a first-rate job in maintaining a high standard of content and presentation. The book is well produced with the exception of a few half-tone illustrations (especially photomicrographs) which have lost detail. Extensive geographical and subject indexes are provided. I recommend this book as essential reading for anyone with the remotest research interest in weathering processes and related landform development. It should also be an essential purchase for all serious undergraduate libraries; given the length and high-quality content of the book (including some colour illustrations), the price is not unreasonable. Although it does not provide all of the answers, the book provides a valuable summary of many of the outstanding questions and uncertainties relating to weathering which remain to be addressed.

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THE PHYSICS OF GLACIERS, third edition, by W. S. B. Paterson, Elsevier, Oxford, New York and Tokyo, 1994. No. of pages: ix + 480. Price £25.00. ISBN 0080379443.

Glaciology has advanced enormously in the 13 years since the second edition of *The Physics of Glaciers* was

published, and a third edition was becoming desperately needed. This edition has been substantially rewritten and updated to incorporate these advances. As with previous editions, the book's aim is to explain the physical principles underlying the behaviour of glaciers and ice sheets. The author rightly makes no apology for introducing mathematics, though the mathematical context is not excessive and the book is dominated by text, tables and

figures rather than equations. It expertly interweaves physical principles expressed in mathematical form with empirical observations described in prose.

The 15 chapters are more logically arranged than in the second edition. Chapter 1 provides a brief history of glaciological research, although longer, more useful treatments of this subject are provided by Clarke (1987) and Hambrey (1994). Chapter 2 is concerned with the transformation of snow to ice and includes an up-to-date description of the processes of snow metamorphosis. Chapter 3, on glacier mass balance, has important sections about the measurements and results of mass balance studies of valley glaciers and ice sheets. The heat budget and climatology of glaciers are presented in Chapter 4, which includes a lucid account of energy balance theory and six case studies ranging from East Antarctica to Switzerland. However, an overall synthesis of the geographical and climatological controls on glacier energy balance is lacking. A final section on the effect of climatic change on the Greenland Ice Sheet surprisingly has no reference to the work of Oerlemans, and appears isolated given the numerous studies of the effects of climate change on other ice masses.

Ice structure and deformation are discussed in Chapter 5, which describes the structure of individual ice crystals, laboratory studies of the creep behaviour of polycrystalline ice, and the generalized ice deformation law at the glacier scale. Chapter 6, on the hydraulics of glaciers, includes empirical and theoretical studies of glacier hydrology. The excellent theory section includes Röthlisberger's and Shreve's early work and the more recent work of Kamb, Walder and Fowler on the hydrology of glaciers resting on both hard and soft substrates. The empirical section is weaker, neglecting, for example, recent dye-tracing and hydrochemical studies, both of which have done much to elucidate glacier drainage systems. Chapter 7 deals with theories and observations of glacier sliding. The theories of Weertman, Nye and Kamb are clearly and thoroughly explained as is Iken's more recent theory of sliding with cavitation. Unfortunately, the sliding with cavitation theories of Lliboutry and Fowler are largely ignored. Till deformation is examined in Chapter 8, which covers rheological properties of till and existing, field-based flow relations for till. This is a highly illuminating and stimulating chapter, highlighting discrepancies between previous work rather than providing a consensus.

Chapter 9 considers structures and fabrics in glaciers and ice sheets, the former being virtually identical to coverage in the second edition, and the latter being substantially updated to include recent data obtained from Antarctic and Greenland ice cores. The temperature distribution of glaciers and ice sheets is covered in Chapter 10. It includes a thorough section on temperate glaciers

but no equivalent section on cold or polythermal glaciers. Chapter 11 deals with steady flow in glaciers and ice sheets. It examines controls on the surface profiles of ice sheets, and principles and applications of the continuity, stress and velocity equations. It then covers theory and observation of the velocity distribution across valley glaciers, along flow lines and at ice divides. Chapter 12 covers the flow of ice shelves and ice streams. Non-steady flow of glaciers and ice sheets is covered in Chapter 13, which explains physically how ice masses respond to mass balance changes. Numerical modelling of glacier variations is usefully covered. Models of present and former ice sheet flow are considered in detail, but those of valley glacier flow are only briefly mentioned. Chapter 14 is about surging and tidewater glaciers, reviewing surging glacier characteristics and surge mechanisms for glaciers on different substrates, and tidewater glaciers (although with just a single paragraph on Heinrich Events). Finally, Chapter 15 outlines various ice core techniques (e.g. isotopes, CO₂, dust) and, with reference to recent work (including GRIP and GISP-2), discusses how they have improved our understanding of climatic change over the last 100 000 years.

The third edition of *The Physics of Glaciers* provides an exceptionally thorough and extensive treatment of the current state of glaciological knowledge. The single authorship makes for a consistent level of detail and thorough cross-referencing. The only substantial areas not covered are glacial erosion and sedimentation, although these have been addressed in detail by Drewry (1986). Previous editions of this book have informed and inspired a generation of glaciologists, geologists, meteorologists, geophysicists and physical geographers worldwide. This edition will surely do the same for the next generation. In the book's preface, Paterson suggests that 'the vast expansion of literature . . . is making it increasingly difficult for one person to write a comprehensive account of the physics of glaciers' and that he will not be producing a fourth edition. I hope, therefore, that he encourages somebody else to write such an accessible, informative and useful book on glacier physics in about ten years or so.

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